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Chen et al.

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(54) **CAMERA OPTICAL LENS INCLUDING SIX LENSES OF +---+--- REFRACTIVE POWERS**

(58) **Field of Classification Search**
CPC G02B 9/62; G02B 13/0045
See application file for complete search history.

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(56) **References Cited**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

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(30) **Foreign Application Priority Data**

Jun. 30, 2019 (CN) 201910582038.7

(57) **ABSTRACT**

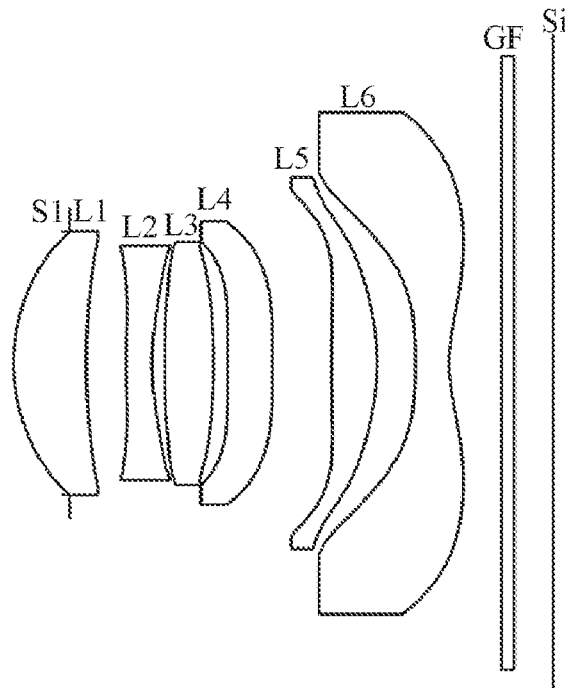
(51) **Int. Cl.**
G02B 13/00 (2006.01)
G02B 9/62 (2006.01)

The present disclosure relates to the technical field of optical lens and discloses a camera optical lens. The camera optical lens includes, from an object side to an image side: a first lens, a second lens, a third lens, a fourth lens, a fifth lens and a sixth lens. The camera optical lens satisfies following conditions: $1.00 \leq f_1/f_2 \leq 1.50$ and $25.00 \leq R_5/d_5 \leq 35.03$, where f denotes a focal length of the camera optical lens; f_1 denotes a focal length of the first lens; R_5 denotes a curvature radius of an object-side surface of the third lens; and d_5 denotes an on-axis thickness of the third lens. The camera optical lens can achieve a high imaging performance while obtaining a low TTL.

(52) **U.S. Cl.**
CPC **G02B 13/0045** (2013.01); **G02B 9/62** (2013.01)

18 Claims, 7 Drawing Sheets

10



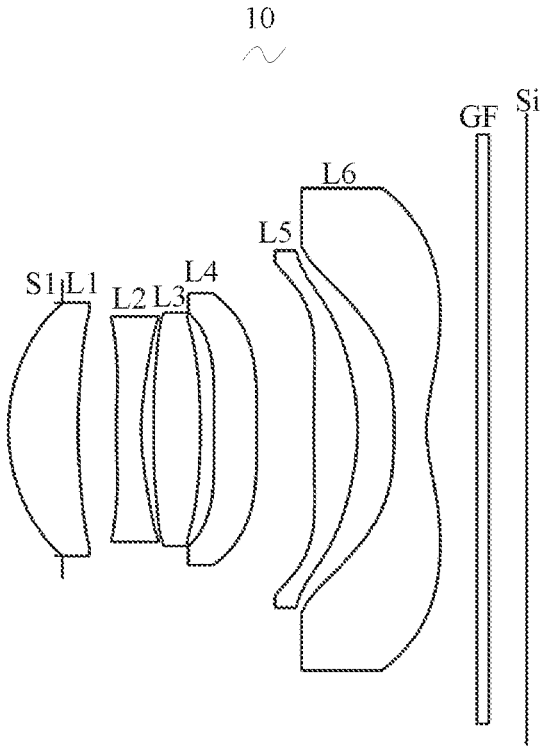


FIG. 1

Longitudinal aberration

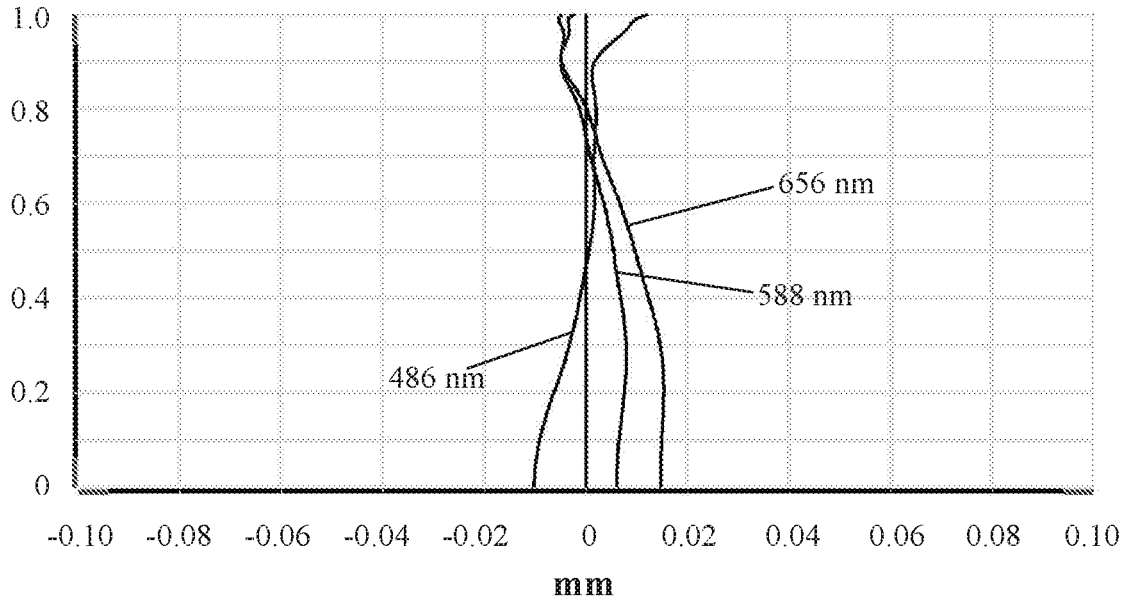


FIG. 2

Lateral color

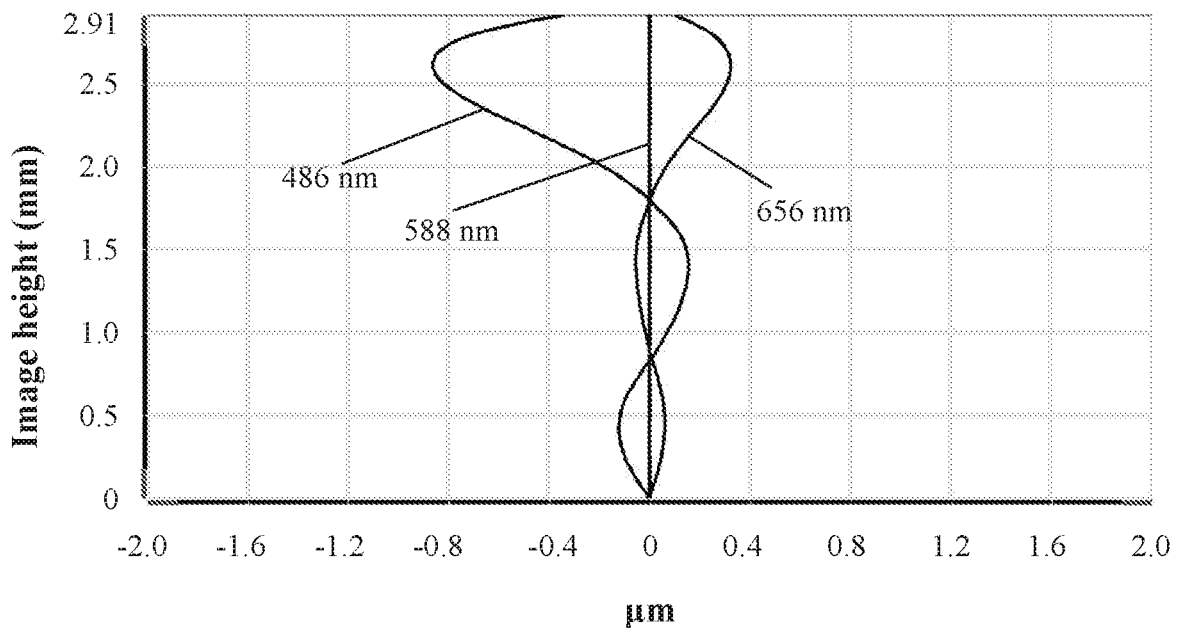


FIG. 3

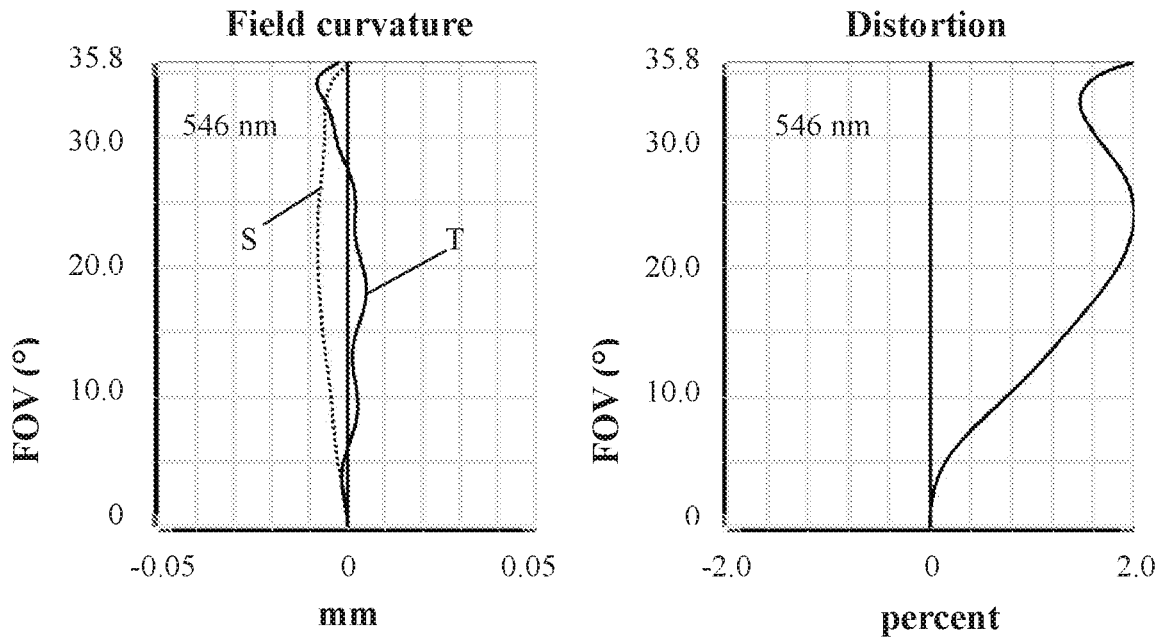


FIG. 4

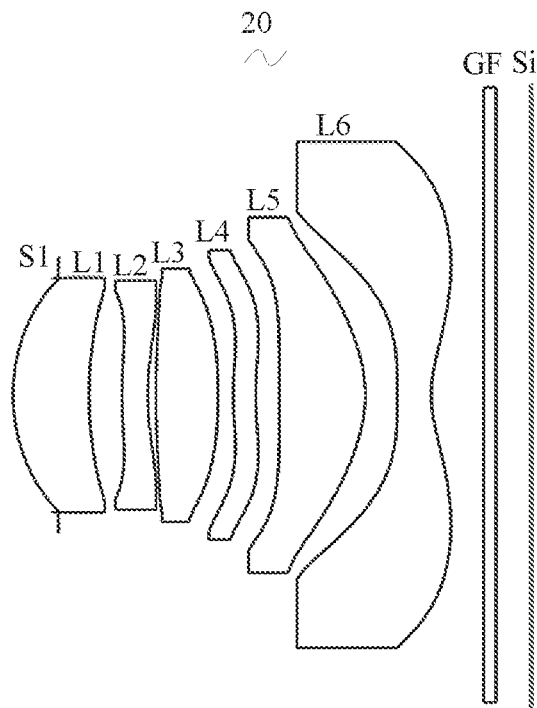
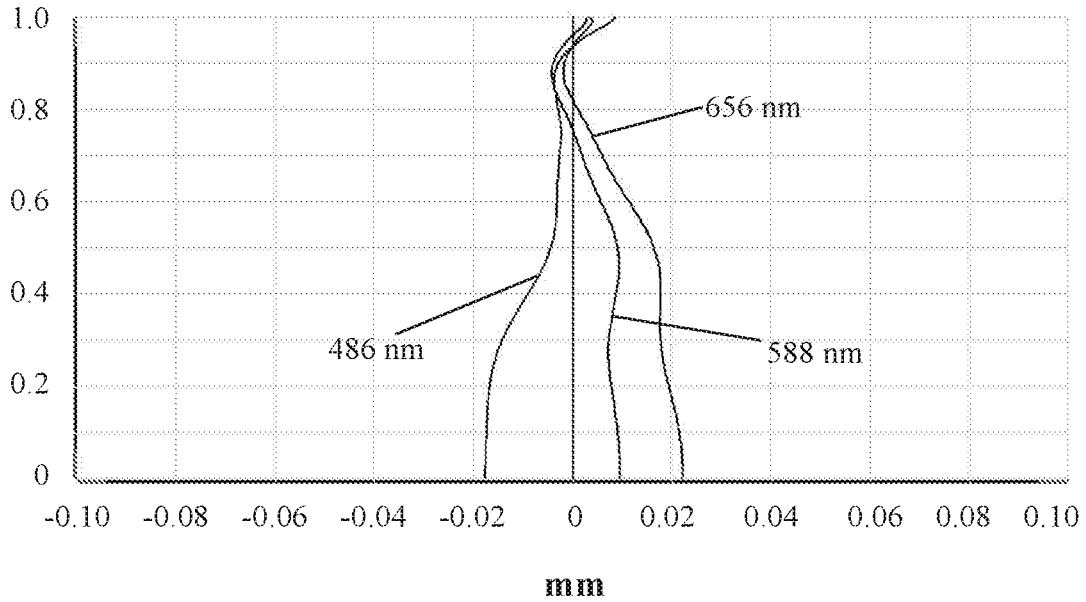


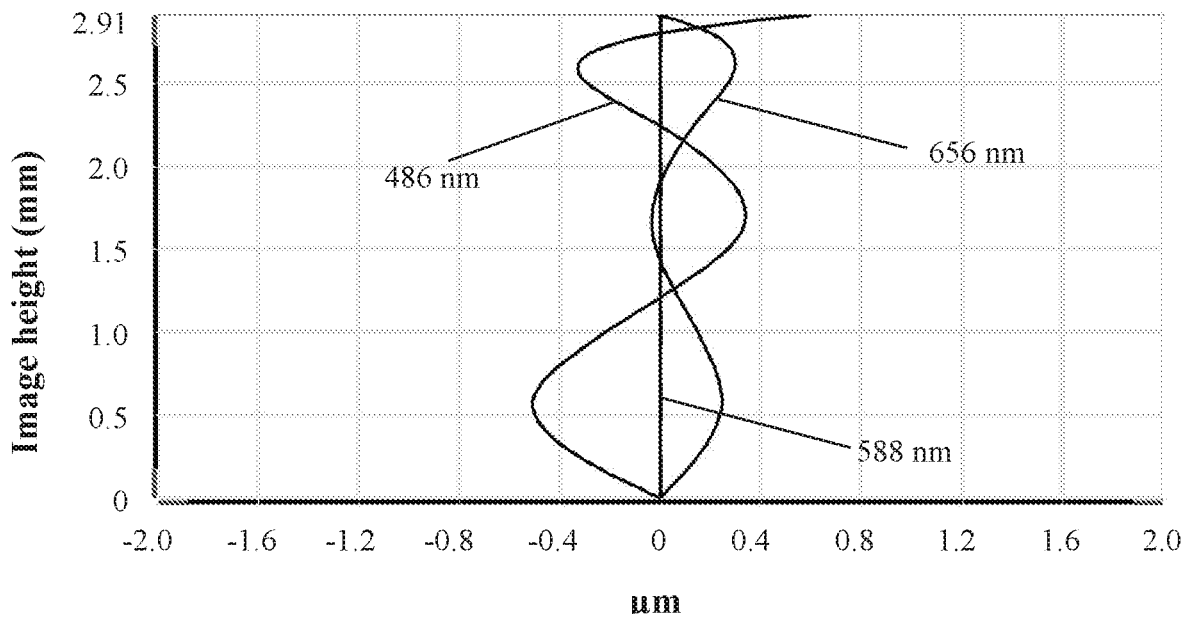
FIG. 5

Longitudinal aberration



mm
FIG. 6

Lateral color



um
FIG. 7

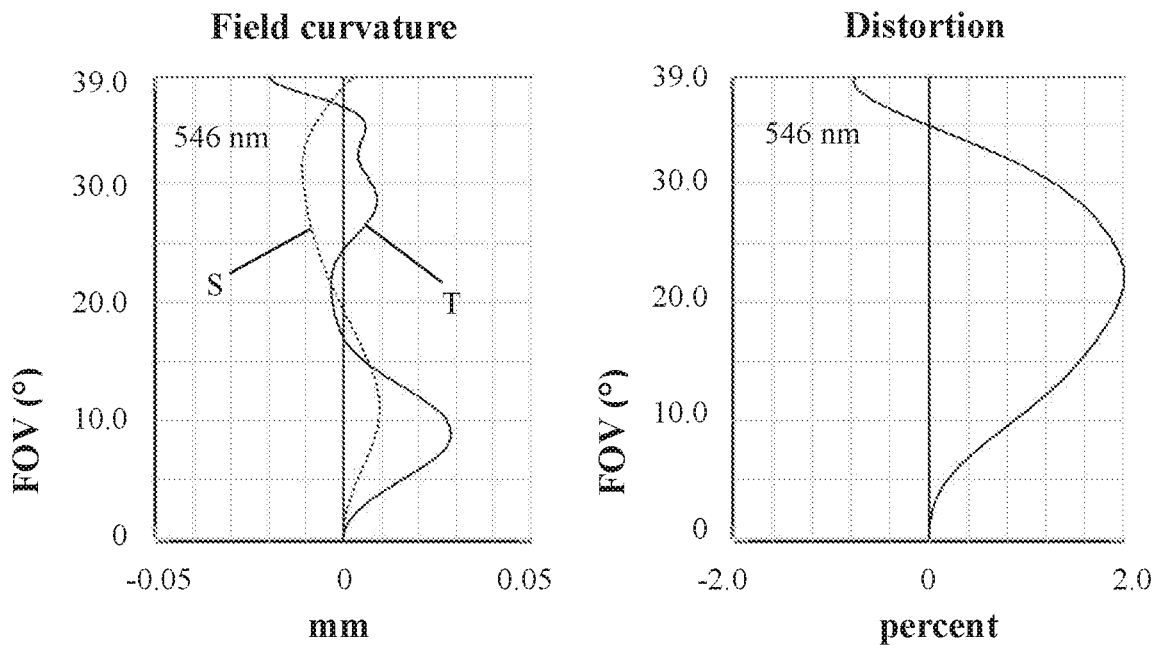


FIG. 8

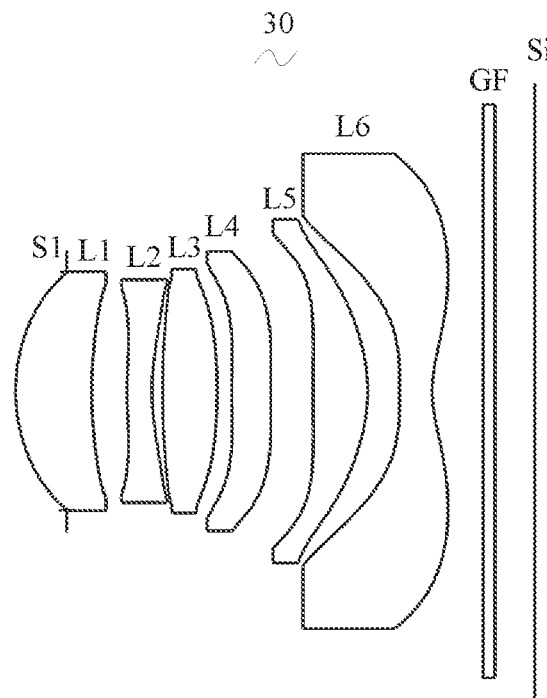


FIG. 9

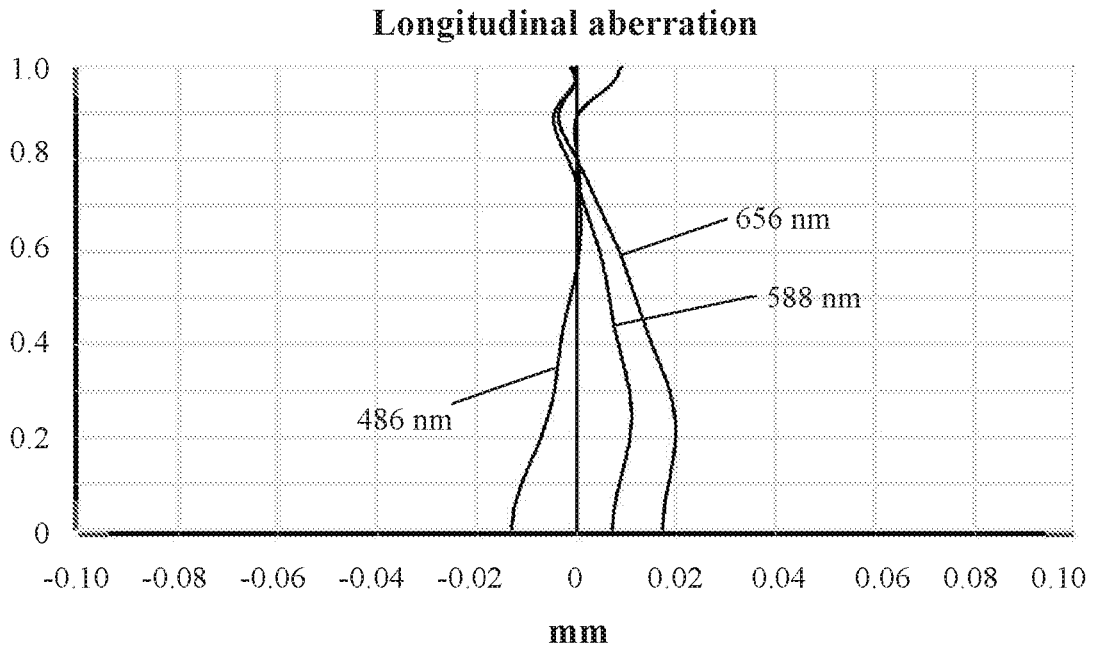


FIG. 10

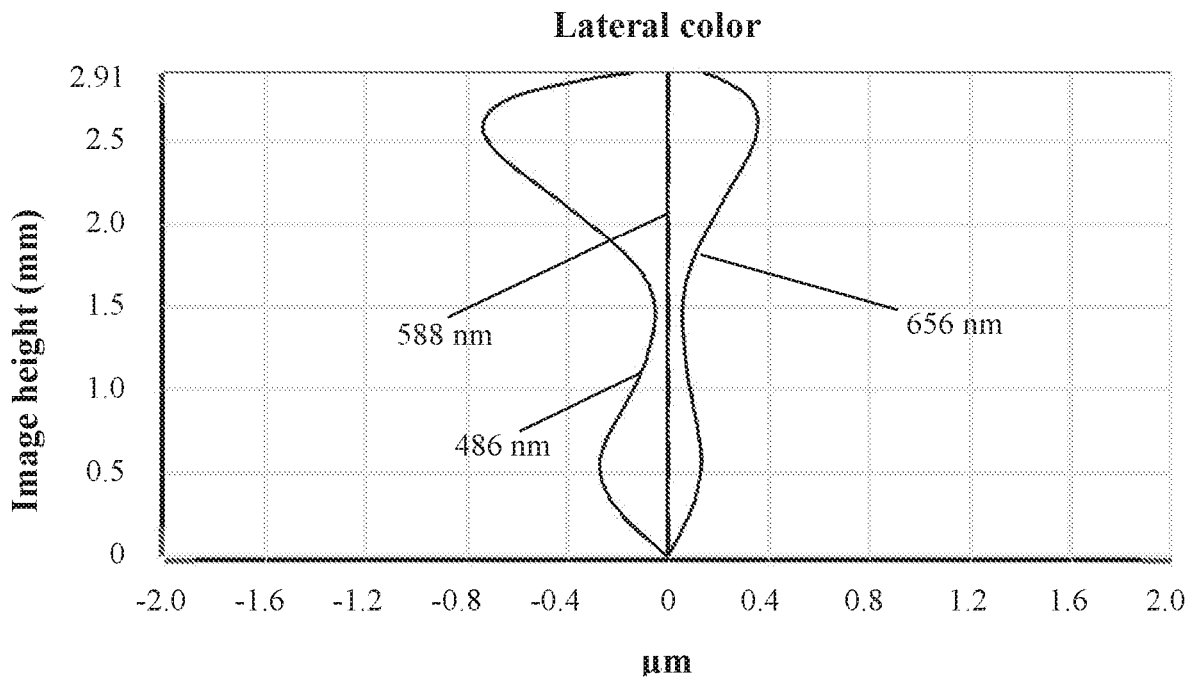


FIG. 11

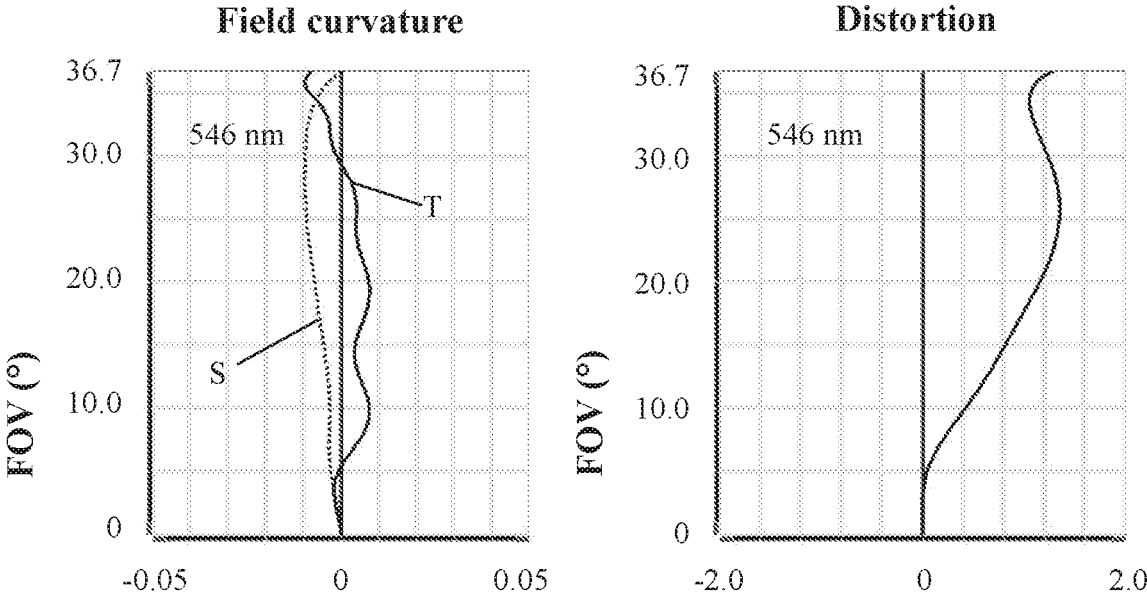


FIG. 12

CAMERA OPTICAL LENS INCLUDING SIX LENSES OF +---+--- REFRACTIVE POWERS

TECHNICAL FIELD

The present disclosure relates to the field of optical lens, in particular, to a camera optical lens suitable for handheld devices, such as smart phones and digital cameras, and imaging devices, such as monitors or PC lenses.

BACKGROUND

With the emergence of smart phones in recent years, the demand for miniature camera lens is increasing day by day, but in general the photosensitive devices of camera lens are nothing more than Charge Coupled Device (CCD) or Complementary Metal-Oxide Semiconductor Sensor (CMOS sensor), and as the progress of the semiconductor manufacturing technology makes the pixel size of the photosensitive devices become smaller, plus the current development trend of electronic products towards better functions and thinner and smaller dimensions, miniature camera lens with good imaging quality therefore have become a mainstream in the market. In order to obtain better imaging quality, the lens that is traditionally equipped in mobile phone cameras adopts a three-piece or four-piece lens structure. Also, with the development of technology and the increase of the diverse demands of users, and as the pixel area of photosensitive devices is becoming smaller and smaller and the requirement of the system on the imaging quality is improving constantly, the five-piece, six-piece and seven-piece lens structure gradually appear in lens designs. There is an urgent need for ultra-thin wide-angle camera lenses which with good optical characteristics and fully corrected aberration.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram of a structure of a camera optical lens according to Embodiment 1 of the present disclosure.

FIG. 2 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 1.

FIG. 3 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 1.

FIG. 4 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 1.

FIG. 5 is a schematic diagram of a structure of a camera optical lens according to Embodiment 2 of the present disclosure.

FIG. 6 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 5.

FIG. 7 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 5.

FIG. 8 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 5.

FIG. 9 is a schematic diagram of a structure of a camera optical lens according to Embodiment 3 of the present disclosure.

FIG. 10 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 9.

FIG. 11 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 9.

FIG. 12 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 9.

DETAILED DESCRIPTION OF EMBODIMENTS

To make the objects, technical solutions, and advantages of the present disclosure clearer, embodiments of the present

disclosure are described in detail with reference to accompanying drawings in the following. A person of ordinary skill in the art can understand that, in the embodiments of the present disclosure, many technical details are provided to make readers better understand the present disclosure. However, even without these technical details and any changes and modifications based on the following embodiments, technical solutions required to be protected by the present disclosure can be implemented.

Embodiment 1

Referring to the accompanying drawings, the present disclosure provides a camera optical lens 10. FIG. 1 shows the camera optical lens 10 of Embodiment 1 of the present disclosure, the camera optical lens 10 includes six lenses. Specifically, the camera optical lens 10 includes, from an object side to an image side: an aperture S1, a first lens L1, a second lens L2, a third lens L3, a fourth lens L4, a fifth lens L5 and a sixth lens L6. An optical element such as an optical filter GF can be arranged between the sixth lens L7 and an image surface Si.

The first lens L1, the second lens L2, the third lens L3, the fourth lens L4, the fifth lens L5 and the sixth lens L6 are all made of plastic material.

The second lens L2 has a negative refractive power, and the third lens L3 has a positive refractive power.

Here, a focal length of the camera optical lens 10 is defined as f , a focal length of the first lens L1 is defined as f_1 , and the camera optical lens 10 should satisfy a condition of $1.00 \leq f_1/f \leq 1.50$, which specifies a positive refractive power of the first lens L1. A value lower than a lower limit may facilitate a development towards ultra-thin lenses, but the positive refractive power of the first lens L1 may be too powerful to correct such a problem as aberration, which is unbeneficial for a development towards wide-angle lenses. On the contrary, a value higher than an upper limit may weaken the positive refractive power of the first lens L1, and it will be difficult to realize the development towards ultra-thin lenses. Preferably, the camera optical lens 10 further satisfies a condition of $1.02 \leq f_1/f \leq 1.49$.

A curvature radius of an object-side surface of the third lens L3 is defined as R_5 , an on-axis thickness of the third lens L3 is defined as d_5 , and the camera optical lens 10 further satisfies a condition of $25.00 \leq R_5/d_5 \leq 35.03$, which specifies a shape of the third lens L1. Within this range, a development towards ultra-thin and wide-angle lenses would facilitate correcting a problem like the aberration. Preferably, the camera optical lens 10 further satisfies a condition of $25.05 \leq R_5/d_5 \leq 35.03$.

A total optical length from an object-side surface of the first lens L1 to the image surface Si of the camera optical lens along an optical axis is defined as TTL.

When a focal length f of the camera optical lens 10, the focal length f_1 of the first lens L1, a curvature radius R_5 of the object-side surface of the third lens L3 and an on-axis thickness d_5 of the third lens L3 all satisfy the above conditions, the camera optical lens 10 has an advantage of high performance and satisfies a design requirement of low TTL.

In an embodiment, an object-side surface of the first lens L1 is convex in a paraxial region, an image-side surface of the first lens L1 is concave in the paraxial region, and the first lens L1 has a positive refractive power.

A curvature radius of the object-side surface of the first lens L1 is defined as R_1 , a curvature radius of the image-side surface of the first lens L1 is defined as R_2 , and the camera

optical lens **10** further satisfies a condition of $-5.98 \leq (R1+R2)/(R1-R2) \leq -1.23$. This can reasonably control a shape of the first lens **L1** in such a manner that the first lens **L1** can effectively correct a spherical aberration of the camera optical lens. Preferably, the camera optical lens **10** further satisfies a condition of $-3.74 \leq (R1+R2)/(R1-R2) \leq -1.54$.

An on-axis thickness of the first lens **L1** is defined as $d1$, and the camera optical lens **10** further satisfies a condition of $0.07 \leq d1/TTL \leq 0.22$. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.11 \leq d1/TTL \leq 0.18$.

In an embodiment, an object-side surface of the second lens **L2** is convex in the paraxial region, and an image-side surface of the second lens **L2** is concave in the paraxial region.

The focal length of the camera optical lens **10** is defined as f , the focal length of the second lens **L2** is defined as $f2$, and the camera optical lens **10** further satisfies a condition of $-6.39 \leq f2/f \leq -0.95$. By controlling a negative refractive power of the second lens **L2** within a reasonable range, correction of the aberration of the optical system can be facilitated. Preferably, the camera optical lens **10** further satisfies a condition of $-3.99 \leq f2/f \leq -1.19$.

A curvature radius of the object-side surface of the second lens **L2** is defined as $R3$, a curvature radius of the image-side surface of the second lens **L2** is defined as $R4$, and the camera optical lens **10** further satisfies a condition of $1.12 \leq (R3+R4)/(R3-R4) \leq 7.19$, which specifies a shape of the second lens **L2**. Within this range, a development towards ultra-thin and wide-angle lenses would facilitate correcting the problem of the aberration. Preferably, the camera optical lens **10** further satisfies a condition of $1.80 \leq (R3+R4)/(R3-R4) \leq 5.75$.

An on-axis thickness of the second lens **L2** is defined as $d3$, and the camera optical lens **10** further satisfies a condition of $0.02 \leq d3/TTL \leq 0.07$. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.04 \leq d3/TTL \leq 0.06$.

In an embodiment, the object-side surface of the third lens **L3** is convex in the paraxial region, and an image-side surface of the third lens **L3** is convex in the paraxial region.

A focal length of the third lens **L3** is defined as $f3$, and the camera optical lens **10** further satisfies a condition of $0.96 \leq f3/f \leq 3.37$. An appropriate distribution of the refractive power leads to a better imaging quality and a lower sensitivity. Preferably, the camera optical lens **10** further satisfies a condition of $1.54 \leq f3/f \leq 2.70$.

A curvature radius of the object-side surface of the third lens **L3** is defined as $R5$, a curvature radius of the image-side surface of the third lens **L3** is defined as $R6$, and the camera optical lens **10** further satisfies a condition of $0.10 \leq (R5+R6)/(R5-R6) \leq 0.82$, which specifies a shape of the third lens **L3**. Within this range, a development towards ultra-thin and wide-angle lenses would facilitate correcting a problem like the aberration. Preferably, the camera optical lens **10** further satisfies a condition of $0.16 \leq (R5+R6)/(R5-R6) \leq 0.65$.

An on-axis thickness of the third lens **L3** is defined as $d5$, and the camera optical lens **10** further satisfies a condition of $0.05 \leq d5/TTL \leq 0.18$. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.07 \leq d5/TTL \leq 0.14$.

In an embodiment, an object-side surface of the fourth lens **L4** is convex in the paraxial region, and the fourth lens **L4** has a positive refractive power.

A focal length of the fourth lens **L4** is defined as $f4$, and the camera optical lens **10** further satisfies a condition of $2.39 \leq f4/f \leq 48.82$. The appropriate distribution of refractive

power makes it possible that the system has the better imaging quality and the lower sensitivity. Preferably, the camera optical lens **10** further satisfies a condition of $3.83 \leq f4/f \leq 39.06$.

A curvature radius of the object-side surface of the fourth lens **L4** is defined as $R7$, a curvature radius of an image-side surface of the fourth lens **L4** is defined as $R8$, and the camera optical lens **10** further satisfies a condition of $-240.44 \leq (R7+R8)/(R7-R8) \leq -0.56$, which specifies a shape of the fourth lens **L4**. Within this range, a development towards ultra-thin and wide-angle lens would facilitate correcting a problem like an off-axis aberration. Preferably, the camera optical lens **10** further satisfies a condition of $-150.27 \leq (R7+R8)/(R7-R8) \leq -0.70$.

An on-axis thickness of the fourth lens **L4** is defined as $d7$, and the camera optical lens **10** further satisfies a condition of $0.02 \leq d7/TTL \leq 0.12$. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.03 \leq d7/TTL \leq 0.10$.

In an embodiment, an object-side surface of the fifth lens **L5** is convex in the paraxial region, an image-side surface of the fifth lens **L5** is convex in the paraxial region, and the fifth lens **L5** has a positive refractive power.

A focal length of the fifth lens **L5** is defined as $f5$, and the camera optical lens **10** further satisfies a condition of $0.32 \leq f5/f \leq 1.22$, which can effectively make a light angle of the camera lens gentle and reduce an tolerance sensitivity. Preferably, the camera optical lens **10** further satisfies a condition of $0.52 \leq f5/f \leq 0.98$.

A curvature radius of the object-side surface of the fifth lens **L5** is defined as $R9$, a curvature radius of the image-side surface of the fifth lens **L5** is defined as $R10$, and the camera optical lens **10** further satisfies a condition of $0.40 \leq (R9+R10)/(R9-R10) \leq 1.50$, which specifies a shape of the fifth lens **L5**. Within this range, a development towards ultra-thin and wide-angle lenses can facilitate correcting a problem of the off-axis aberration. Preferably, the camera optical lens **10** further satisfies a condition of $0.63 \leq (R9+R10)/(R9-R10) \leq 1.20$.

An on-axis thickness of the fifth lens **L5** is defined as $d9$, and the camera optical lens **10** further satisfies a condition of $0.04 \leq d9/TTL \leq 0.24$. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.07 \leq d9/TTL \leq 0.19$.

In an embodiment, an object-side surface of the sixth lens **L6** is concave in the paraxial region, an image-side surface of the sixth lens **L6** is concave in the paraxial region, and the sixth lens **L6** has a negative refractive power.

A focal length of the sixth lens **L6** is defined as $f6$, and the camera optical lens **10** further satisfies a condition of $-1.06 \leq f6/f \leq -0.33$. The appropriate distribution of refractive power makes it possible that the system has the better imaging quality and lower sensitivity. Preferably, the camera optical lens **10** further satisfies a condition of $-0.67 \leq f6/f \leq -0.42$.

A curvature radius of the object-side surface of the sixth lens **L6** is defined as $R11$, a curvature radius of the image-side surface of the sixth lens **L6** is defined as $R12$, and the camera optical lens **10** further satisfies a condition of $0.38 \leq (R11+R12)/(R11-R12) \leq 1.24$, which specifies a shape of the sixth lens **L6**. Within this range, a development towards ultra-thin and wide-angle lenses would facilitate correcting the problem of the off-axis aberration. Preferably, the camera optical lens **10** further satisfies a condition of $0.60 \leq (R11+R12)/(R11-R12) \leq 0.99$.

An on-axis thickness of the sixth lens **L6** is defined as $d11$, and the camera optical lens **10** further satisfies a condition of

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0.03 ≤ d11/TTL ≤ 0.10. This can facilitate achieving ultra-thin lenses. Preferably, the camera optical lens 10 further satisfies a condition of 0.05 ≤ d11/TTL ≤ 0.08.

In an embodiment, the focal length of the camera optical lens is defined as f, a combined focal length of the first lens and the second lens is defined as f12, and the camera optical lens 10 further satisfies a condition of 1.11 ≤ f12/f ≤ 3.46. This can eliminate the aberration and distortion of the camera optical lens and reduce a back focal length of the camera optical lens, thereby maintaining miniaturization of the camera optical lens. Preferably, the camera optical lens 10 further satisfies a condition of 1.78 ≤ f12/f ≤ 2.77.

In an embodiment, the total optical length TTL of the camera optical lens 10 is less than or equal to 5.28 mm, which is beneficial for achieving ultra-thin lenses. Preferably, the total optical length TTL of the camera optical lens 10 is less than or equal to 5.04 mm.

In an embodiment, the camera optical lens 10 has a large aperture, and an F number of the camera optical lens 10 is less than or equal to 2.22. Preferably, the F number of the camera optical lens 10 is less than or equal to 2.17.

With such designs, the total optical length TTL of the camera optical lens 10 can be made as short as possible, thus the miniaturization characteristics can be maintained.

In the following, examples will be used to describe the camera optical lens 10 of the present disclosure. The symbols recorded in each example will be described as follows. The focal length, on-axis distance, curvature radius, on-axis thickness, inflexion point position, and arrest point position are all in units of mm.

TTL: Optical length (the total optical length from the object-side surface of the first lens to the image surface of the camera optical lens along the optical axis) in mm.

Preferably, inflexion points and/or arrest points can be arranged on the object-side surface and/or the image-side surface of the lens, so as to satisfy the demand for high quality imaging. The description below can be referred for specific implementations.

The design data of the camera optical lens 10 in Embodiment 1 of the present disclosure are shown in Table 1 and Table 2.

TABLE 1

	R	d	nd	vd
S1	∞	d0 = -0.496		
R1	1.688	d1 = 0.646	nd 1.5467	v1 55.82
R2	5.664	d2 = 0.354	1	
R3	5.918	d3 = 0.230	nd 1.6686	v2 20.53
R4	2.272	d4 = 0.113	2	
R5	11.358	d5 = 0.434	nd 1.5467	v3 55.82
R6	-7.553	d6 = 0.126	3	
R7	13.247	d7 = 0.396	nd 1.6422	v4 23.83
R8	-149.717	d8 = 0.529	4	
R9	16.942	d9 = 0.406	nd 1.5467	v5 55.82
R10	-1.957	d10 = 0.336	5	
R11	-9.317	d11 = 0.300	nd 1.5375	v6 56.12
R12	1.305	d12 = 0.470	6	
R13	∞	d13 = 0.110	nd 1.5168	vg 64.17
R14	∞	d14 = 0.348	g	

In the table, meanings of various symbols will be described as follows.

S1: aperture;

R: curvature radius of an optical surface, a central curvature radius for a lens;

R1: curvature radius of the object-side surface of the first lens L1;

R2: curvature radius of the image-side surface of the first lens L1;

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R3: curvature radius of the object-side surface of the second lens L2;

R4: curvature radius of the image-side surface of the second lens L2;

R5: curvature radius of the object-side surface of the third lens L3;

R6: curvature radius of the image-side surface of the third lens L3;

R7: curvature radius of the object-side surface of the fourth lens L4;

R8: curvature radius of the image-side surface of the fourth lens L4;

R9: curvature radius of the object-side surface of the fifth lens L5;

R10: curvature radius of the image-side surface of the fifth lens L5;

R11: curvature radius of the object-side surface of the sixth lens L6;

R12: curvature radius of the image-side surface of the sixth lens L6;

R13: curvature radius of an object-side surface of the optical filter GF;

R14: curvature radius of an image-side surface of the optical filter GF;

d: on-axis thickness of a lens and an on-axis distance between lens;

d0: on-axis distance from the aperture S1 to the object-side surface of the first lens L1;

d1: on-axis thickness of the first lens L1;

d2: on-axis distance from the image-side surface of the first lens L1 to the object-side surface of the second lens L2;

d3: on-axis thickness of the second lens L2;

d4: on-axis distance from the image-side surface of the second lens L2 to the object-side surface of the third lens L3;

d5: on-axis thickness of the third lens L3;

d6: on-axis distance from the image-side surface of the third lens L3 to the object-side surface of the fourth lens L4;

d7: on-axis thickness of the fourth lens L4;

d8: on-axis distance from the image-side surface of the fourth lens L4 to the object-side surface of the fifth lens L5;

d9: on-axis thickness of the fifth lens L5;

d10: on-axis distance from the image-side surface of the fifth lens L5 to the object-side surface of the sixth lens L6;

d11: on-axis thickness of the sixth lens L6;

d12: on-axis distance from the image-side surface of the seventh lens L7 to the object-side surface of the optical filter GF;

d13: on-axis thickness of the optical filter GF;

d14: on-axis distance from the image-side surface to the image surface of the optical filter GF;

nd: refractive index of the d line;

nd1: refractive index of the d line of the first lens L1;

nd2: refractive index of the d line of the second lens L2;

nd3: refractive index of the d line of the third lens L3;

nd4: refractive index of the d line of the fourth lens L4;

nd5: refractive index of the d line of the fifth lens L5;

nd6: refractive index of the d line of the sixth lens L6;

ndg: refractive index of the d line of the optical filter GF;

vd: abbe number;

v1: abbe number of the first lens L1;

v2: abbe number of the second lens L2;

v3: abbe number of the third lens L3;

v4: abbe number of the fourth lens L4;

v5: abbe number of the fifth lens L5;

v6: abbe number of the sixth lens L6;

vg: abbe number of the optical filter GF.

Table 2 shows aspherical surface data of the camera optical lens 10 in Embodiment 1 of the present disclosure.

TABLE 2

	Conic coefficient k	Aspheric surface coefficients			
		A4	A6	A8	A10
R1	3.6087E-02	-7.1999E-04	4.4234E-03	2.4454E-02	-1.3901E-01
R2	8.4725E+00	-3.0090E-02	7.0304E-03	4.1841E-02	-1.1996E-01
R3	1.6114E+01	-2.4370E-01	1.1989E-01	-7.4213E-02	5.1050E-01
R4	-1.1350E+01	-5.7653E-02	8.3168E-03	-1.0096E-01	7.4031E-01
R5	8.9183E+01	6.0383E-02	-1.7107E-02	-2.9136E-01	5.4022E-01
R6	-9.9000E+01	-1.5666E-01	4.1634E-01	-1.1786E+00	2.7371E+00
R7	-1.0538E+01	-2.7654E-01	2.5342E-01	-2.3294E-01	-3.8935E-01
R8	9.9000E+01	-1.8498E-01	-3.2914E-03	2.7385E-01	-8.1276E-01
R9	-9.2153E+01	1.4755E-02	-1.1873E-01	6.3283E-02	7.4126E-02
R10	-1.3179E+00	1.4318E-01	-2.1795E-01	1.6315E-01	-2.3138E-02
R11	6.5055E+00	-4.1910E-01	3.7712E-01	-2.8446E-01	1.8719E-01
R12	-8.4350E+00	-2.1582E-01	2.0092E-01	-1.3643E-01	6.4208E-02

	Aspheric surface coefficients				
	A12	A14	A16	A18	A20
R1	3.6036E-01	-5.0454E-01	4.0319E-01	-1.7274E-01	3.1150E-02
R2	2.1985E-01	-2.5991E-01	1.9697E-01	-8.7267E-02	1.7655E-02
R3	-1.3193E+00	1.7199E+00	-1.2863E+00	5.2522E-01	-9.0658E-02
R4	-1.6881E+00	2.1399E+00	-1.5969E+00	6.6609E-01	-1.2241E-01
R5	-2.3986E-01	-5.7810E-01	1.0698E+00	-6.8531E-01	1.5450E-01
R6	-4.8305E+00	5.7299E+00	-4.2261E+00	1.7608E+00	-3.1476E-01
R7	1.8429E+00	-3.3312E+00	3.2399E+00	-1.6517E+00	3.4705E-01
R8	1.3323E+00	-1.3526E+00	8.3377E-01	-2.8562E-01	4.1615E-02
R9	-2.0168E-01	1.8813E-01	-8.9659E-02	2.1897E-02	-2.1722E-03
R10	-9.2557E-02	9.0732E-02	-3.7235E-02	7.3123E-03	-5.6669E-04
R11	-1.0788E-01	4.8181E-02	-1.3919E-02	2.2398E-03	-1.5318E-04
R12	-2.0801E-02	4.4963E-03	-6.1427E-04	4.7563E-05	-1.5738E-06

Here, K is a conic coefficient, and A4, A6, A8, A10, A12, A14, A16, A18 and A20 are aspheric surface coefficients.

IH: Image height

$$y = (x^2/R) / [1 + \{1 - (k+1)(x^2/R^2)\}^{1/2}] + A4x^4 + A6x^6 + A8x^8 + A10x^{10} + A12x^{12} + A14x^{14} + A16x^{16} + A18x^{18} + A20x^{20} \quad (1)$$

For convenience, an aspheric surface of each lens surface uses the aspheric surfaces shown in the above formula (1). However, the present disclosure is not limited to the aspherical polynomials form shown in the formula (1).

Table 3 and Table 4 show design data of inflexion points and arrest points of the camera optical lens 10 according to Embodiment 1 of the present disclosure. P1R1 and P1R2 represent the object-side surface and the image-side surface of the first lens L1, P2R1 and P2R2 represent the object-side surface and the image-side surface of the second lens L2, P3R1 and P3R2 represent the object-side surface and the image-side surface of the third lens L3, P4R1 and P4R2 represent the object-side surface and the image-side surface of the fourth lens L4, P5R1 and P5R2 represent the object-side surface and the image-side surface of the fifth lens L5, and P6R1 and P6R2 represent the object-side surface and the image-side surface of the sixth lens L6. The data in the column named “inflexion point position” refer to vertical distances from inflexion points arranged on each lens surface to the optic axis of the camera optical lens 10. The data in the column named “arrest point position” refer to vertical distances from arrest points arranged on each lens surface to the optical axis of the camera optical lens 10.

TABLE 3

	Number(s) of inflexion points	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	0			
P1R2	0			
P2R1	1	0.265		
P2R2	0			
P3R1	0			
P3R2	1	0.945		
P4R1	1	0.155		
P4R2	0			
P5R1	3	0.425	1.475	1.545
P5R2	2	1.305	1.645	
P6R1	2	1.345	1.705	
P6R2	2	0.435	2.255	

TABLE 4

	Number(s) of arrest points	Arrest point position 1
P1R1	0	
P1R2	0	
P2R1	1	0.465
P2R2	0	
P3R1	0	
P3R2	0	
P4R1	1	0.275
P4R2	0	
P5R1	1	0.635
P5R2	0	
P6R1	0	
P6R2	1	1.065

FIG. 2 and FIG. 3 illustrate a longitudinal aberration and a lateral color with wavelengths of 486 nm, 588 nm and 656 nm after passing the camera optical lens 10 according to Embodiment 1, respectively. FIG. 4 illustrates a field curvature and a distortion with a wavelength of 546 nm after passing the camera optical lens 10 according to Embodiment 1. A field curvature S in FIG. 4 is a field curvature in a sagittal direction, and T is a field curvature in a tangential direction.

Table 13 in the following shows various values of Embodiments 1, 2, 3 and values corresponding to parameters which are specified in the above conditions.

As shown in Table 13, Embodiment 1 satisfies the above conditions.

In this Embodiment, an entrance pupil diameter of the camera optical lens is 2.345 mm, an image height of 1.0H is 2.911 mm, an FOV (field of view) in a diagonal direction is 71.53°. Thus, the camera optical lens has a wide-angle and

TABLE 5

	R	d	nd	vd
S1	∞	d0 = -0.404		
5 R1	1.678	d1 = 0.679	nd	1.5467 v1 55.82
R2	3.363	d2 = 0.295	1	
R3	3.789	d3 = 0.230	nd	1.6686 v2 20.53
R4	2.481	d4 = 0.075	2	
R5	19.370	d5 = 0.553	nd	1.5467 v3 55.82
R6	-5.721	d6 = 0.138	3	
10 R7	3.117	d7 = 0.200	nd	1.6422 v4 23.83
R8	3.169	d8 = 0.211	4	
R9	1044.423	d9 = 0.767	nd	1.5467 v5 55.82
R10	-1.283	d10 = 0.288	5	
R11	-11.786	d11 = 0.302	nd	1.5375 v6 56.12
R12	1.101	d12 = 0.470	6	
15 R13	∞	d13 = 0.110	nd	1.5168 vg 64.17
R14	∞	d14 = 0.417	g	

Table 6 shows aspherical surface data of each lens of the camera optical lens 20 in Embodiment 2 of the present disclosure.

TABLE 6

	Conic coefficient	Aspheric surface coefficients			
		k	A4	A6	A8
R1	5.3805E-02	7.3359E-03	1.2156E-04	-3.3667E-02	1.7628E-01
R2	7.0106E+00	-5.8154E-02	1.9815E-01	-1.0552E+00	3.0002E+00
R3	3.6314E+00	-2.3169E-01	1.2441E-02	-2.8839E-01	1.0707E+00
R4	-2.0799E+01	4.5584E-02	-3.6132E-01	7.2199E-01	-1.1070E+00
R5	9.8995E+01	1.1115E-01	-3.7351E-01	1.1794E+00	-2.4801E+00
R6	5.8405E+00	-1.7822E-01	1.1541E-01	7.0161E-02	-3.4188E-01
R7	-9.9000E+01	-1.0006E-01	-5.9895E-01	1.4858E+00	-1.9364E+00
R8	-6.6678E+01	-7.7693E-02	-4.1330E-01	8.7706E-01	-1.0053E+00
R9	-3.9537E+01	-2.8546E-02	-6.8146E-02	8.9008E-02	-7.7927E-02
R10	-1.7104E+00	1.0925E-01	-1.5571E-01	1.2530E-01	-5.0929E-02
R11	2.1678E+01	-4.2478E-01	4.6457E-01	-5.0779E-01	4.5275E-01
R12	-6.7533E+00	-1.9844E-01	1.7662E-01	-1.1765E-01	5.4413E-02

Aspheric surface coefficients					
	A12	A14	A16	A14	A16
R1	-2.7674E-01	1.9819E-01	-5.0706E-02	-4.0321E-03	2.5088E-03
R2	-4.5750E+00	3.5350E+00	-1.0583E+00	-1.8965E-02	-1.7639E-02
R3	-1.6871E+00	1.2928E+00	-3.7522E-01	1.1976E-02	-5.7118E-02
R4	9.7373E-01	-3.1858E-01	-1.4959E-02	9.8190E-04	4.1663E-03
R5	2.6545E+00	-1.3273E+00	2.4614E-01	-6.8737E-05	1.0377E-03
R6	4.2875E-01	-2.6250E-01	6.8752E-02	1.0349E-04	1.2983E-05
R7	1.4484E+00	-5.6338E-01	8.7108E-02	2.3051E-04	1.5868E-04
R8	6.5704E-01	-2.2219E-01	3.0265E-02	-5.1510E-05	7.9882E-05
R9	3.1295E-02	-4.1627E-03	-1.8745E-04	1.9139E-05	2.4177E-05
R10	3.1633E-03	3.9246E-03	-7.5083E-04	-4.4485E-06	-5.3690E-06
R11	-2.9354E-01	1.3267E-01	-3.9970E-02	7.2465E-03	-5.9181E-04
R12	-1.7129E-02	3.5673E-03	-4.6878E-04	3.5064E-05	-1.1303E-06

is ultra-thin. Its on-axis and off-axis aberrations are fully corrected, thereby achieving excellent optical characteristics.

Table 7 and table 8 show design data of inflexion points and arrest points of each lens of the camera optical lens 20 lens according to Embodiment 2 of the present disclosure.

Embodiment 2

TABLE 7

	Number(s) of inflexion points	Inflexion point position 1	Inflexion point position 2
60 P1R1	0		
P1R2	1	0.915	
P2R1	1	0.315	
P2R2	1	0.495	
65 P3R1	2	0.645	0.855
P3R2	1	1.035	

Embodiment 2 is basically the same as Embodiment 1 and involves symbols having the same meanings as Embodiment 1, and only differences therebetween will be described in the following.

Table 5 and Table 6 show design data of a camera optical lens 20 in Embodiment 2 of the present disclosure.

TABLE 7-continued

	Number(s) of inflexion points	Inflexion point position 1	Inflexion point position 2
P4R1	2	0.265	1.075
P4R2	2	0.305	1.145
P5R1	2	0.055	1.335
P5R2	2	1.305	1.585
P6R1	2	1.425	1.655
P6R2	2	0.465	2.285

TABLE 8

	Number of arrest points	Arrest point position 1
P1R1	0	
P1R2	0	
P2R1	1	0.545
P2R2	1	1.005
P3R1	0	
P3R2	0	
P4R1	1	0.475
P4R2	1	0.535
P5R1	1	0.095
P5R2	0	
P6R1	0	
P6R2	1	1.185

FIG. 6 and FIG. 7 illustrate a longitudinal aberration and a lateral color of light with wavelengths of 486 nm, 588 nm and 656 nm after passing the camera optical lens 20 according to Embodiment 2. FIG. 8 illustrates a field curvature and a distortion of light with a wavelength of 546 nm after passing the camera optical lens 20 according to Embodiment 2.

As shown in Table 13, Embodiment 2 satisfies the above conditions.

In an embodiment, an entrance pupil diameter of the camera optical lens is 2.141 mm, an image height of 1.0H is 2.911 mm, an FOV (field of view) in the diagonal direction

is 78.06°. Thus, the camera optical lens has a wide-angle and is ultra-thin. Its on-axis and off-axis aberrations are fully corrected, thereby achieving excellent optical characteristics.

Embodiment 3

Embodiment 3 is basically the same as Embodiment 1 and involves symbols having the same meanings as Embodiment 1, and only differences therebetween will be described in the following.

Table 9 and Table 10 show design data of a camera optical lens 30 in Embodiment 3 of the present disclosure.

TABLE 9

	R	d	nd	vd
S1	∞	d0 = -0.474		
R1	1.689	d1 = 0.704	nd	1.5467 v1 55.82
R2	4.384	d2 = 0.328	1	
R3	4.663	d3 = 0.230	nd	1.6686 v2 20.53
R4	2.275	d4 = 0.098	2	
R5	12.655	d5 = 0.504	nd	1.5467 v3 55.82
R6	-5.845	d6 = 0.133	3	
R7	8.456	d7 = 0.361	nd	1.6422 v4 23.83
R8	15.649	d8 = 0.393	4	
R9	59.666	d9 = 0.506	nd	1.5467 v5 55.82
R10	-1.539	d10 = 0.296	5	
R11	-9.082	d11 = 0.300	nd	1.5375 v6 56.12
R12	1.170	d12 = 0.470	6	
R13	∞	d13 = 0.110	nd	1.5168 vg 64.17
R14	∞	d14 = 0.367	g	

Table 10 shows aspherical surface data of each lens of the camera optical lens 30 in Embodiment 3 of the present disclosure.

TABLE 10

	Conic coefficient	Aspheric surface coefficients								
		k	A4	A6	A8	A10	A12	A14	A16	A14
R1	9.9933E-02	-5.4702E-05	1.5443E-02	-2.5379E-02	1.4223E-02	9.7472E-02	-2.3756E-01	2.5049E-01	-1.2950E-01	2.7335E-02
R2	9.3640E+00	-3.3249E-02	-1.7662E-04	9.4464E-02	-2.9338E-01	5.4792E-01	-5.8657E-01	3.4061E-01	-8.5673E-02	4.2617E-03
R3	6.6463E+00	-2.4525E-01	3.2501E-02	-1.5199E-02	6.2216E-01	-1.7308E+00	2.4027E+00	-1.9561E+00	8.9108E-01	-1.7797E-01
R4	-1.4178E+01	-5.7115E-03	-1.7400E-01	2.3300E-01	1.3627E-01	-7.6732E-01	1.1140E+00	-8.5085E-01	3.6123E-01	-7.1044E-02
R5	9.8939E+01	7.4014E-02	-4.9492E-02	-1.6260E-01	1.5571E-01	4.5543E-01	-1.3822E+00	1.6310E+00	-8.9820E-01	1.8853E-01
R6	-1.9488E+01	-1.4045E-01	1.4785E-01	5.1609E-02	-7.9784E-01	1.7387E+00	-2.0514E+00	1.4202E+00	-5.2580E-01	7.9785E-02
R7	-5.8037E+01	-2.4294E-01	1.3755E-01	6.6271E-02	-4.9806E-01	8.7245E-01	-9.1714E-01	6.0917E-01	-2.2597E-01	3.5340E-02
R8	-9.9000E+01	-1.6868E-01	-4.5936E-02	3.2339E-01	-6.9041E-01	9.0132E-01	-7.7413E-01	4.2178E-01	-1.3138E-01	1.7868E-02
R9	-9.9000E+01	5.1280E-03	-1.3469E-01	6.9230E-02	1.2139E-01	-2.8066E-01	2.5723E-01	-1.2733E-01	3.3328E-02	-3.5953E-03
R10	-1.5436E+00	1.5733E-01	-2.6742E-01	2.0405E-01	-5.8365E-03	-1.3854E-01	1.2558E-01	-5.1674E-02	1.0506E-02	-8.5609E-04
R11	1.0122E+01	-4.4833E-01	4.5318E-01	-4.7161E-01	5.0475E-01	-4.3180E-01	2.4493E-01	-8.3618E-02	1.5483E-02	-1.1922E-03
R12	-8.0513E+00	-2.1070E-01	1.9045E-01	-1.2118E-01	5.2572E-02	-1.5624E-02	3.1015E-03	-3.8893E-04	2.7379E-05	-8.0147E-07

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Table 11 and Table 12 show design data inflexion points and arrest points of the respective lenses in the camera optical lens 30 according to Embodiment 3 of the present disclosure.

TABLE 11

	Number(s) of inflexion points	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	0			
P1R2	0			
P2R1	1	0.285		
P2R2	2	0.565	0.745	
P3R1	0			
P3R2	1	0.995		
P4R1	2	0.205	1.105	
P4R2	2	0.175	1.255	
P5R1	3	0.285	1.415	1.505
P5R2	2	1.275	1.655	
P6R1	1	1.395		
P6R2	2	0.435	2.265	

TABLE 12

	Number of arrest points	Arrest point position 1
P1R1	0	
P1R2	0	
P2R1	1	0.505
P2R2	0	
P3R1	0	
P3R2	0	
P4R1	1	0.365
P4R2	1	0.305
P5R1	1	0.415
P5R2	0	
P6R1	0	
P6R2	1	1.125

FIG. 10 and FIG. 11 illustrate a longitudinal aberration and a lateral color of light with wavelengths of 486 nm, 588 nm and 656 nm after passing the camera optical lens 30 according to Embodiment 3. FIG. 12 illustrates a field curvature and a distortion of light with a wavelength of 546 nm after passing the camera optical lens 30 according to Embodiment 3.

Table 13 in the following lists values corresponding to the respective conditions in an embodiment according to the above conditions. Obviously, the embodiment satisfies the above conditions.

In an embodiment, an entrance pupil diameter of the camera optical lens is 1.781 mm, an image height of 1.OH is 2.911 mm, an FOV (field of view) in the diagonal direction is 73.38°. Thus, the camera optical lens has a wide-angle and is ultra-thin. Its on-axis and off-axis aberrations are fully corrected, thereby achieving excellent optical characteristics.

TABLE 13

Parameters and conditions	Embodiment 1	Embodiment 2	Embodiment 3
f	3.962	3.618	3.833
f1	4.160	5.359	4.599
f2	-5.660	-11.56	-6.91
f3	8.366	8.141	7.384
f4	18.967	117.777	28.097
f5	3.233	2.345	2.751
f6	-2.110	-1.858	-1.909
f12	8.897	8.053	8.837

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TABLE 13-continued

Parameters and conditions	Embodiment 1	Embodiment 2	Embodiment 3
FNO	1.69	1.69	2.15
f1/f	1.05	1.48	1.20
R5/d5	26.17	35.03	25.11

It can be appreciated by one having ordinary skill in the art that the description above is only embodiments of the present disclosure. In practice, one having ordinary skill in the art can make various modifications to these embodiments in forms and details without departing from the scope of the present disclosure.

What is claimed is:

1. A camera optical lens comprising, from an object side to an image side:

- a first lens;
- a second lens having a negative refractive power;
- a third lens having a positive refractive power;
- a fourth lens having a positive refractive power;
- a fifth lens; and
- a sixth lens;

wherein the camera optical lens consists of six lenses, and further satisfies following conditions:

$$1.78 \leq f12/f2.77;$$

$$1.00 \leq f1/f \leq 1.50; \text{ and}$$

$$25.00 \leq R5/d5 \leq 35.03;$$

where

f denotes a focal length of the camera optical lens;

f12 denotes a combined focal length of the first lens and the second lens;

f1 denotes a focal length of the first lens;

R5 denotes a curvature radius of an object-side surface of the third lens; and

d5 denotes an on-axis thickness of the third lens.

2. The camera optical lens according to claim 1 further satisfying following conditions:

$$1.02 \leq f1/f \leq 1.49; \text{ and}$$

$$25.05 \leq R5/d5 \leq 35.03.$$

3. The camera optical lens according to claim 1, wherein the first lens has a positive refractive power, an object-side surface of the first lens is convex in a paraxial region and an image-side surface of the first lens is concave in the paraxial region; and

the camera optical lens further satisfies following conditions:

$$-5.98 \leq (R1+R2)/(R1-R2) \leq -1.23; \text{ and}$$

$$0.07 \leq d1/TTL \leq 0.22;$$

Where

R1 denotes a curvature radius of the object-side surface of the first lens;

R2 denotes a curvature radius of the image-side surface of the first lens;

d1 denotes an on-axis thickness of the first lens; and

TTL denotes a total optical length from the object-side surface of the first lens to an image surface of the camera optical lens along an optical axis.

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4. The camera optical lens according to claim 3 further satisfying following conditions:

$$-3.74 \leq (R1+R2)/(R1-R2) \leq -1.54; \text{ and}$$

$$0.11 \leq d1/TTL \leq 0.18.$$

5. The camera optical lens according to claim 1, wherein an object-side surface of the second lens is convex in a paraxial region, an image-side surface of the second lens is concave in the paraxial region, and

the camera optical lens further satisfies following conditions:

$$-6.39 \leq f2/f \leq -0.95;$$

$$1.12 \leq (R3+R4)/(R3-R4) \leq 7.19; \text{ and}$$

$$0.02 \leq d3/TTL \leq 0.07;$$

where

f2 denotes a focal length of the second lens;

R3 denotes a curvature radius of the object-side surface of the second lens;

R4 denotes a curvature radius of the image-side surface of the second lens;

d3 denotes an on-axis thickness of the second lens; and TTL denotes a total optical length from an object-side surface of the first lens to an image surface of the camera optical lens along an optical axis.

6. The camera optical lens according to claim 5 further satisfying following conditions:

$$-3.99 \leq f2/f \leq -1.19;$$

$$1.80 \leq (R3+R4)/(R3-R4) \leq 0.75; \text{ and}$$

$$0.04 \leq d3/TTL \leq 0.06.$$

7. The camera optical lens according to claim 1, wherein the object-side surface of the third lens is convex in a paraxial region, an image-side surface of the third lens is convex in a paraxial region, and

the camera optical lens further satisfies following conditions:

$$0.96 \leq f3/f \leq 3.37;$$

$$0.10 \leq (R5+R6)/(R5-R6) \leq 0.82; \text{ and}$$

$$0.05 \leq d5/TTL \leq 0.18;$$

where

f3 is a focal length of the third lens;

R5 denotes a curvature radius of the object-side surface of the third lens;

R6 denotes a curvature radius of the image-side surface of the third lens;

d5 denotes an on-axis thickness of the third lens; and TTL denotes a total optical length from an object-side surface of the first lens to an image surface of the camera optical lens along an optical axis.

8. The camera optical lens according to claim 7 further satisfying following conditions:

$$1.54 \leq f3/f \leq 2.70;$$

$$0.16 \leq (R5+R6)/(R5-R6) \leq 0.65; \text{ and}$$

$$0.07 \leq d5/TTL \leq 0.14.$$

9. The camera optical lens according to claim 1, wherein the fourth lens has a positive refractive power, an object-side surface of the fourth lens is convex in a paraxial region, and

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the camera optical lens further satisfies following conditions:

$$2.39 \leq f4/f \leq 48.82;$$

$$5 \quad -240.44 \leq (R7+R8)/(R7-R8) \leq -0.56; \text{ and}$$

$$0.02 \leq d7/TTL \leq 0.12;$$

where

f4 is a focal length of the fourth lens;

10 R7 denotes a curvature radius of the object-side surface of the fourth lens;

R8 denotes a curvature radius of an image-side surface of the fourth lens;

15 d7 denotes an on-axis thickness of the fourth lens; and TTL denotes a total optical length from an object-side surface of the first lens to an image surface of the camera optical lens along an optical axis.

10. The camera optical lens according to claim 9 further satisfying following conditions:

$$3.83 \leq f4/f \leq 39.06;$$

$$-150.27 \leq (R7+R8)/(R7-R8) \leq -0.70; \text{ and}$$

$$0.03 \leq d7/TTL \leq 0.10.$$

11. The camera optical lens according to claim 1, wherein the fifth lens has a positive refractive power, an object-side surface of the fifth lens is convex in a paraxial region, an image-side surface of the fifth lens is convex in the paraxial region, and

the camera optical lens further satisfies following conditions:

$$0.32 \leq f5/f \leq 1.22;$$

$$35 \quad 0.40 \leq (R9+R10)/(R9-R10) \leq 1.50; \text{ and}$$

$$0.04 \leq d9/TTL \leq 0.24;$$

where

f5 denotes a focal length of the fifth lens;

40 R9 denotes a curvature radius of the object-side surface of the fifth lens;

R10 denotes a curvature radius of the image-side surface of the fifth lens;

45 d9 denotes an on-axis thickness of the fifth lens; and TTL denotes a total optical length from an object-side surface of the first lens to an image surface of the camera optical lens along an optical axis.

12. The camera optical lens according to claim 11 further satisfying following conditions:

$$0.52 \leq f5/f \leq 0.98;$$

$$0.63 \leq (R9+R10)/(R9-R10) \leq 1.20; \text{ and}$$

$$0.07 \leq d9/TTL \leq 0.19.$$

13. The camera optical lens according to claim 1, wherein the sixth lens has a negative refractive power, an object-side surface of the sixth lens is concave in a paraxial region, an image-side surface of the sixth lens is concave in the paraxial region, and

the camera optical lens further satisfies following conditions:

$$-1.06 \leq f6/f \leq -0.33;$$

$$65 \quad 0.38 \leq (R11+R12)/(R11-R12) \leq 1.24; \text{ and}$$

$$0.03 \leq d11/TTL \leq 0.10;$$

where

f6 denotes a focal length of the sixth lens;

R11 denotes a curvature radius of the object-side surface
of the sixth lens;

R12 denotes a curvature radius of the image-side surface 5
of the sixth lens;

d11 denotes an on-axis thickness of the sixth lens; and

TTL denotes a total optical length from an object-side
surface of the first lens to an image surface of the
camera optical lens along an optical axis. 10

14. The camera optical lens according to claim **13** further
satisfying following conditions:

$$-0.67 \leq f_6/f_s \leq -0.42;$$

$$0.60 \leq (R_{11} + R_{12}) / (R_{11} - R_{12}) \leq 0.99; \text{ and} \quad 15$$

$$0.05 \leq d_{11} / TTL \leq 0.08.$$

15. The camera optical lens according to claim **1**, where
a total optical length TTL from an object-side surface of the
first lens to an image surface of the camera optical lens along
an optical axis is less than or equal to 5.28 mm. 20

16. The camera optical lens according to claim **15**,
wherein the total optical length TTL of the camera optical
lens is less than or equal to 5.04 mm.

17. The camera optical lens according to claim **1**, wherein 25
an F number of the camera optical lens is less than or equal
to 2.22.

18. The camera optical lens according to claim **17**,
wherein the F number of the camera optical lens is less than
or equal to 2.17. 30

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